Remarks made at the Demonstration of the Röntgen Ray, at Stated Meeting, February 21, 1896.

Prof. Goodspeed describes his apparatus as follows:

In order to economize time it may be worth while for me to call your attention very briefly to the apparatus that we will use to-night, before beginning the reading of the regular paper. We have here two terminal wires which are supplied with the electric current from several storage batteries which are behind a screen. The electro-motive force is about sixteen volts. This induction coil which is to furnish the current to stimulate the tube has a primary resistance of about three-tenths ohm. The resistance of the secondary coil is about 3200 ohms, dead resistance. By passing the primary current through the small resistance coil and interrupting it frequently, as you all know, we produce an induced current in the high resistance secondary coil. It is the discharge of this induced current through the Crookes tube which you see here that produces the green phosphorescence and secondarily, probably, produces or sets up the form of energy with which we are to deal this evening.

In order to make a test case I will place this little pocketbook, with a couple of coins and an iron key inside it, upon a sensitive photographic plate, which is placed upon the table wrapped in several thicknesses of light-tight paper. The plate, as you will see, is three or four inches below the lower end of the tube. The tube is much larger than is usually seen; and for that reason, probably, is more efficient. The internal pressure is probably about one one-millionth of an atmosphere. The exposure may continue during the reading of the paper. Subsequently we will have the plate developed.

The Röntgen Phenomena.

Gentlemen:—Never before in the history of science has a new discovery commanded such intense and universal interest as that, some of the features of which we have met here to-night to witness. Less than two months ago, the civilized world was startled at the unofficial announcement that Prof. Röntgen, of Würzburg, had discovered a form of energy probably related to radiation, which would pass through many substances that were opaque to known forms of ether energy. An interesting point in this connection was that glass, ordinarily so transparent to light, seemed to be quite opaque to the new energy. Since the original paper of Röntgen has appeared, we have learned that the discovery referred to resulted from a series of experiments on fluorescence. The important pieces of apparatus that were used, and which we have before us this evening, consist of an inductorium with its secondary coil connected to a well-exhausted Crookes tube. A high degree of exhaustion is noted by the absence of a bluish halo about one or both of the terminals. The internal pressure is about one one-millionth of an atmosphere. The earliest form of vacuum tube, constructed nearly fifty years ago, was exhausted to about one one-hundredth of an atmosphere, and on the passage of an electric discharge, glowed throughout its length with a purplish-blue color. As the efficiency of the pump increased, higher vacuum became easy and the phenomenon of the dark space about the cathode was described and exhibited to the British Association by Crookes in 1879. As the exhaustion is increased the dark space may enlarge so as to extend throughout the length of the tube. Under these conditions, the position of the anode is of little consequence, and under the action of the discharge the whole bulb becomes fluorescent with green or blue according to the kind of glass.

"Cathode rays" is a term applied to the disturbance which seems to start at the cathode within the tube, and extend in straight lines to the opposite side. These rays are capable of being deflected by a magnet, and were supposed by Crookes to consist of the molecules of the residual gas projected with great speed from the cathode terminal and impinging upon the walls of the tube. In the language of molecular kinetics, it may be said, then, that the mean free path of the molecule in one of these highly exhausted tubes, has become greater than the length of the tube. It was discovered in 1890 by Hertz that these cathode rays can pass through some solid substances, *e. g.*, aluminum, while others he found to be opaque. Lenard, the assistant of Hertz, in 1894, passed the cathode rays outside the tube, through a small aluminum window, placed in the wall of the tube opposite the cathode. This window had to be very thin to facilitate the issue of the rays, and yet thick enough, compared with its size, to withstand the pressure of the atmosphere. Consequently, the area was very small. Lenard also obtained shadow records on photographic plates by interposing, between the aluminum window and the plate, opaque bodies.

The cathode rays when impinging upon the Lenard window do not issue in a direction collinear with their former direction; but seem to spread in all directions like a beam of light passing beyond a very small aperture. The transparency of substances for these rays seemed to be closely related to their density. For example, in the case of gases, hydrogen was found to behave like oxygen if it were compressed until its density became equal to that of the oxygen. Transparency to these rays seemed to have no relation to electric conductivity.

With reference to leaving out the aluminum window and replacing it by merely the glass of the tube, Lenard said (*Electrician*, Vol. xxxii, p. 576): "On replacing the aluminum window by one of glass, it was found "possible to repeat all the essential experiments with equal success. But the aluminum remains the more suitable, not that it is the more transparent, but because aluminum is opaque to light, and more easily manipulated than glass of equal thickness." So we see that Lenard actually obtained results in about the same way that we are experimenting now. Dr. Oliver Lodge, of Liverpool, tried two years ago to repeat this very experiment, with a tube of rather thick glass, "Failing," to use his own words, "simply by reason of insufficient pertinacity." This is doubtless the case, since Lodge has lately repeated Röntgen's experiment with that same tube, obtaining results "through a quarter inch of wood and a sheet of aluminum, provided something like a half an hour's exposure is allowed" (*Electrician*, Vol. xxxvi, p. 438).

Opinions differ as to whether the rays used by Lenard were the same as those producing the Röntgen phenomena. As has been said, cathode rays are deflected by a magnet, while the Röntgen rays seem not to be. The Lenard rays, also, were shown to be capable of deflection by a magnet under certain conditions. Röntgen, himself, is of the opinion that the new energy is some form of ether wave motion perhaps longitudinal, and Lord Kelvin, I think, maintains the same views. Other English authorities seem to be divided between the ultra-violet theory and the longitudinal wave theory.

Dr. Lodge in a lecture before the Liverpool Physical Society, January 27, 1896, expressed himself as rather favoring the opinion that the Röntgen rays are highly electrified material particles, traveling with very great velocity. In a recent article (*Electrician*, Vol. xxxvi, p. 430), Lodge says, that "He permits himself to doubt and inclines to a sort of electrolytic impulsive propagation, through and by means of ordinary matter; in spite of the immensely important fact that Prof. Röntgen can detect in his rays no magnetic deflectibility whatever." In concluding the article referred to, Lodge says, "Meanwhile, the possibility, even the probability, that in these rays we have a new kind of radiation, even though it be only ultra-violet, so high up as to be comparable to the size of molecules, lends to these experiments a prodigious interest in the eyes of physicists, far surpassing the obvious practical applications which have gained the ear of the general public."

Since writing the above, Lodge has himself repeated the magnetic experiment with very great care, finding no deflection (*Electrician*, Vol. xxxvi, p. 471), and expresses himself as follows: "Consequently, the hypothesis of a stream of electrified particles is definitely disproved, as no doubt had already been done in reality by Prof. Röntgen himself."

It seems that Lenard had arrived at the conclusion that he was dealing with two classes of rays, as regards their deflectibility by a magnet. The question may still arise then, May not the Röntgen rays be the undeflectible Lenard rays?

The ultra-violet theory is said to be favored by Professors Schuster and Fitzgerald. One difficulty is, that some electrical conductors are practically transparent to the new radiation. To waves of light of every kind they ought to be opaque according to Maxwell's theory. However, the fact that gold and some other metals, when excessively thin, are translucent has long presented a difficulty, which is only partially overcome by the assumption, that "the structure is not infinitely fine-grained, with respect to the size of the light waves." It may not be too much to suppose that these new waves are comparable in size with the molecules, or even the atoms, of matter.

The theory of Prof. Röntgen, already referred to, that the new energy is longitudinal ether-wave motion, surely must not be ignored, especially as it seems to be supported, among others, by the distinguished mathematical physicist, Prof. Boltzmann, of Vienna. There are difficulties in supposing the ether to be compressible, yet it must assume the effects of compressibility, if it is to transmit a periodic disturbance with finite speed.

Röntgen's own theory seems well supported by G. Jaumann (Wiedemann's *Annalen*, January, 1896), who has shown in a recent article that by a little change in Maxwell's equations, to satisfy the conditions of high rarefaction, which is met with in a Crookes tube, longitudinal ether waves are possible, which would possess many of the properties of the new rays.

That the new energy does not consist of cathode rays alone, seems to be proved by the remarkable experiment of J. J. Thomson, who placed a protected plate inside the vacuum tube, exposed to the direct cathode stream, and got no result (Lodge, *Electrician*, Vol. xxxvi, p. 473). The same experimenter has suggested an efficient and quick way of detecting the presence of Röntgen rays. An insulated metal plate electrically charged, either positively or negatively, quickly loses its charge when in the presence of the rays. This occurs even when the plate is entirely embedded in the best insulators. It follows, then, that all substances become electrical conductors, when under the influence of the Röntgen discharge.

Should the longitudinal ether-wave theory be demonstrated to be the true one, Prof. Röntgen's discovery would be the greatest of the age, and will open up a vast new field for experimental research, and will likely lead to more definite views concerning the nature of the luminiferous ether.

Soon after the announcement of this wonderful discovery, we began to experiment in the Physical Laboratory of the University of Pennsylvania, at first rather skeptically and quite in the dark as to the exact method of procedure. As the earlier statements implied the necessity of two induction coils, the primary of one connected to the secondary of the other, we were somewhat embarrassed as we did not have two that could be efficiently joined in that way. To show the importance attached to this point by early imitators of Röntgen abroad, let me quote a statement by A. A. C. Swinton, who, I am told, was the first in England to repeat some of Röntgen's experiments. He says (*Nature*, Vol. liii, p. 277), "So far as our own experiments go, it appears that, at any rate, without very long exposures, a sufficiently active excitation of the

Crookes tube is not obtained by direct connection to an ordinary Rhumkorff induction coil, even of a large size. So called 'high frequency currents,' however, appear to give good results, and our own experiments have been made with a tube excited by current, obtained from the secondary circuit of a Tesla oil coil through the primary of which were continually discharged twelve half gallon Leyden jars, charged with an alternating current of about twenty thousand volts pressure, produced by a transformer with a spark gap across its high-pressure terminals."

Having no such apparatus as this at the University, and thinking that possibly some indication might be obtained from a simpler arrangement, we left out the second coil and joined the tube directly to the secondary of the first coil. The coil we are using was constructed by Apps, of London. It has a primary resistance of about 0.3 of an ohm, and a secondary resistance of about 3200 ohms. The Crookes tube which is one of the collection in the physical cabinet at the University, is a shadow tube nearly twenty-five centimeters long and eleven centimeters in diameter at its larger end.

The first result that was unmistakably a success was obtained on Wednesday, February 5. A small slip of glass and a piece of sheet lead, together with a wedge of wood, were held in place upon a sensitive photographic plate by elastic bands, and the whole enclosed light tight in an ordinary plate holder. This was placed horizontally upon a table, eight or ten centimeters below the large end of the Crookes tube. An exposure of twenty minutes produced, upon development, a sharp impression of the objects, the glass and lead appearing opaque, while the portion of the plate covered by the wood was hardly less affected than the parts entirely unprotected. The sight was startling at first as every experimenter who gets the result for the first time can testify. This experiment was immediately followed by an attempt to obtain a skeleton view of the hand, the result of which will be shown by the first slide.

From that time until the present, many experiments of a varied nature have been tried, the object being to investigate substances with reference to their transparency; to detect, if possible, refraction or reflection; to determine the action of various crystals cut in different ways with reference to the optic axis; and a few experiments to test the possible efficiency of a special method of treating the sensitive film.

Early associated with the writer was Dr. H. W. Cattell, who obtained some very curious cases of malformation of the hand and fingers, and produced results which have proved extremely interesting from a surgical point of view.

Our experiments on crystals have not resulted in much that is interesting, except, perhaps, in one case which I will refer to presently. One plate exposed had upon it a tourmaline, a double image prism, a Nicol prism, an amethyst, an irregular quartz crystal, some mica discs, and some quartz plates with parallel sides. These all seemed to be rather opaque, though I think the exposure was probably too short. We shall experiment in this line at another time.

The second slide shows the skeleton of a lady's hand, which, as far as I know, is the first that has been produced.

The third slide illustrates the difference in the density of the negative caused by times of exposure on the four quarters of the plate of five, ten, twenty, forty-five minutes respectively. During the exposure of each quarter, the rest of the plate was protected by metallic screens. The test objects on the plate, are: a circular piece of cork; a gold coin; a strip of magnesium tape; a piece of glass, and a piece of aluminum. The distance of the tube from the plate was about ten and a half centimeters during all four exposures.

The fourth slide shows the skeleton of a mouse, taken laid flat upon its back; the legs being stretched out and brought as near the plate as possible.

Slide No. 5 shows the density of the negative produced by five-minute exposures, at distances of two and a half centimeters, five centimeters, seven and a half centimeters, ten centimeters and twelve and a half centimeters respectively. The plate was protected by a screen of copper having a circular aperture about one centimeter in diameter.

Slides No. 6 and 7 show the density produced at a distance of two and a half centimeters, with exposures of one to five minutes. These slides were also prepared to demonstrate the efficiency of a plate especially sensitized by Mr. John Carbutt of this city for this work. He conceived the idea that the photographic plate might be rendered more sensitive to this energy, if the film were treated with some fluorescent substance. Mr. Carbutt very kindly placed in our hands some of the special plates, and your attention is directed to a comparison between a very rapid ordinary plate (Seed's No. 27), and the one especially prepared. The treatment throughout was precisely the same. The prepared plate seems to have been considerably more sensitive than the other.

Slides Nos. 8 and 9 show the results of tests to demonstrate the possibility of reflection or refraction, by means of two large diamonds set in a ring. First the diamond ring was enclosed in a flat purse with some coins, and certainly the result is very interesting, though, perhaps, it would be premature to say that anything new is proved by it. The ring was next placed open directly upon the covered plate, and exposed in two positions.

Slide No. 10 shows a possible application of the Röntgen process. Wishing to test the value of the method for detecting flaws in metals, the writer requested one of his associates, Dr. Richards, to have prepared three aluminum plates, four or five millimeters thick, with hidden holes, plugs, or any flaws that might seem desirable. Dr. Richards was asked further to prepare a detailed description of the plates, to sign and seal it, and to bring it with him this evening. The aluminum plates have been examined by means of the Röntgen process, and it may be interesting if one of your members will open the envelope and compare the description therein, with the one that will now be detailed. The picture tells its own story pretty well, even to the uninitiated. No. 1 seems to have three circular holes, plugged up with some substance, doubtless aluminum, having the same radiographic density as the material of the plate. No. 2 appears to be perfect. No. 3 has two holes similar to those of No. 1, and a third stopped up through a portion of its length by some substance less transparent than the aluminum, perhaps a piece of copper or iron wire (Dr. Richards' Description of Aluminum Plates).

Our experiments during the last two weeks have been made at all times of the day and evening, sometimes in full daylight, and often with no light at all, except that emitted by the tube. The presence or absence of luminous radiation seems not to make the least difference in the results. We early learned that sharper outlines could be obtained by omitting the usual plate holder, and wrapping the plate in several thicknesses of orange paper. By this means actinic light was excluded, and the objects were brought nearer to the sensitive film. During this series of experiments, the writer has received much assistance and many valuable suggestions from his associates in the department, Dr. H. C. Richards, Dr. R. R. Tatnall and Mr. G. C. McKee.

In connection with this subject, it is desired to direct the attention of the gentlemen present to a remarkable coincidence which can hardly fail to excite interest. In the fall of 1889, the writer received a letter from a prominent gentleman in Philadelphia, asking him to call at a convenient and early date, to be presented to a friend who was desirous of obtaining facilities for some experiments in electric spark photography. On the occasion referred to, the writer had the pleasure of meeting Mr. W. N. Jennings, of Philadelphia, who for many years has been much interested in the photography of lightning. It was Mr. Jennings' wish to photograph electric sparks from various forms of apparatus, in order to compare the results with the lightning pictures which he had already obtained. It is needless to say that the series of experiments, begun at that time, have been continued to the present, as occasion and opportunity have made it convenient.

The particular meeting of interest occurred on the evening of February 22, 1890. Slides 11 to 14 show the result of some of our experiments on that evening. We photographed the brush from a large induction machine, by holding the uncovered plate in various positions near the poles. We also placed coins and brass weights on the plates, sparking them by means of the Apps induction coil in various ways. After finishing the experiments of this sort, the writer brought out from the cabinet quite a variety of Crookes tubes, and showed them to Mr. Jennings simply for his pleasure and amusement. The desirability of getting Mr. Ives to reproduce some of the color effects by means of his beautiful method was suggested. A few days later, Mr. Jennings announced the results of the evening's work and mentioned that several of the plates that had not been exposed directly, but which were developed along with the others, were found to be fogged. He also mentioned one, upon which had appeared a mysterious disc, that he was quite unable to account for as the character of the impression was entirely different from those that had been obtained in the regular way.

The matter was forgotten until about ten days ago, when the writer asked Mr. Jennings to look over the records of our early experiments, to see if we ever exposed a plate entirely covered in the plate-holder. He immediately did so, and found the plate upon which had appeared the mysterious disc. A very reasonable explanation now is suggested. The disc is doubtless the shadow picture of one of the coins made while we were viewing the Crookes tubes. To add still more weight to this theory, we repeated, a few days ago, the experiment in the same way that it must have been made, if at all, on that interesting evening. The original plate and the result of the recent experiment, we have the honor of showing you here. Now, gentlemen, we wish it clearly understood that we claim no credit whatever for what seems to have been a most interesting accident, yet the evidence seems quite convincing that the *first* Röntgen shadow picture was really produced almost exactly six years ago to-night, in the physical lecture room of the University of Pennsylvania.

ARTHUR W. GOODSPEED.

UNIVERSITY OF PENNSYLVANIA, February 21, 1896.

Prof. Edwin J. Houston's Remarks were as follows:

It is unquestionably the fact that although natural truths cry aloud to the scientific inquirer, yet they may long remain unrecognized. We have heard to-night, in the excellent paper Prof. Goodspeed has read, that although the apparatus we have just seen was in the possession of the University of Pennsylvania, and although it undoubtedly long ago produced the Röntgen effects, yet they were undetected. I had myself a similar apparatus in the philosophical cabinet of the Central High School; and the Röntgen rays were unquestionably produced by it, but they were not recognized. Many a case of a curious shadow photograph, appearing mysteriously upon a plate believed to be good, strange shadows coming out, the cause of which could not be detected, were most probably some of these Röntgen photographs.

The paper we have heard has reviewed in so able a manner the comparatively few facts that are known concerning this peculiar form of radiant energy, that I may, in my remarks, be forced to repeat some of its statements, but it may, nevertheless, be of interest to you if I do so in other language.

The term cathode rays is applied to the stream of electrified molecules that pass in a rectilinear direction from the negative electrode, or cathode, of a suitably exhausted vacuum tube. This peculiar effect is not observed to any marked degree until the residual atmosphere in the tube has a tension or pressure of but about the one-millionth of an atmosphere, or until that peculiar condition of matter in the tube is obtained, for which Crookes proposed the name of the ultra-gaseous, or radiant state. It appears that wherever the cathode rays strike the walls of the tube, or any suitable substance contained therein, they excite fluorescence. The cathode rays are deflected by magnetic flux. Indeed, they must be so deflected if they consist of streams of electrified molecules ; for, their deflection by magnetic flux is a phenomenon allied to the deflection of a voltaic arc by a magnet, or the deflection of the active wires on an electromagnetic motor, by the flux from the field magnets.

Reviewing briefly the history of the Röntgen discovery, we will find some of the facts to be as follows; viz., Hertz showed that thin metallic films are transparent to the cathode rays. Lenard, an assistant of Hertz, who afterwards took up the investigation both in connection with Hertz and individually, placed an aluminum window in the tube so that the cathode rays impinged on it. You probably noticed, in looking at the radiation from the tube shown by Prof. Goodspeed, that the rays did not light up the entire surface of the tube, but that a spot directly opposite the cathode was markedly excited by the phosphorescence. That is the spot where a peculiar kind of radiation, called the Lenard rays, or the Röntgen rays, was observed ; the Lenard rays in one condition of the vacuum, and the Röntgen rays in another condition of the vacuum. Assuming, that the cause of the Lenard or Röntgen rays is the impact of a molecular stream of electrified particles, most probably molecules, we may inquire as to their origin. They are evidently either disengaged from the substance of the negative electrode or cathode, or they are simply the molecules of residual gas in the highly exhausted tube. Inasmuch as Pupin has shown that electrodeless Crookes tubes, that is, tubes not provided with interior electrodes, produce the same effect, it would seem fair to believe that botht he Lenard and the Röntgen effects may be due to molecular bombardment of the molecules of the residual atmosphere. In these electrodeless tubes, pieces of tinfoil are placed on the outside of the tube, and the terminals of the Ruhmkorff coil being attached to them, discharges are produced by electrostatic induction corresponding to the discharges of the secondary of the Ruhmkorff coil, and all the effects of either the Lenard or the Röntgen rays are produced.

Lenard states that his rays are faintly visible to the eye outside the tube. They are, however, rapidly absorbed by the air, so that at a short distance from the tube they cease to be visible. The Röntgen rays, on the contrary, are invisible to the eye. Both the Lenard and the Röntgen rays produce phosphorescence in phosphorescent materials on which they impinge; they both traverse opaque films of metal; they both produce actinic effects on photographic plates. That the Röntgen rays are something different from the Lenard rays is proved, I think, by the fact that they are not by any means so absorbable by air.

It may be interesting to know how Röntgen's original effects were obtained. He took an ordinary Crookes tube, or at least a tube containing the proper vacuum, and completely covered it with blackened pasteboard so as to render it light tight to ordinary light. He took a paper screen which he painted with a substance capable of being excited by fluorescence, a solution of barium-platino-cyanide. He then found that wherever this screen was impinged on by the Röntgen rays, it fluoresced.

Röntgen found, that his rays, like the Lenard rays, possess the strange power of passing through many substances opaque to ordinary light. It is generally believed that the source of the Röntgen rays is the portion of the glass tube which receives the bombardment of the molecules shot off from the negative electrode. In other words, the Röntgen rays are caused by the cathode rays. That they are not the cathode rays themselves is evident from a brief review of some of their characteristics.

1. The Röntgen rays are invisible to the eye.

2. They excite fluorescence. (In this respect, however, they agree with the cathode rays and the Lenard rays.)

3. They produce actinic effects. In this respect they agree with the Lenard rays, but are entirely differentiated from the cathode rays. A photographic plate has been placed inside a Crookes tube and the cathode rays have been caused to impinge on it. They failed to produce any actinic effects. There are clearly then these differences; the Röntgen rays produce actinic effects; *i. e.*, they possess the power of decomposing a photographic salt placed on a sensitive plate, and are not deflected by a magnet. This latter point has been confirmed recently by some very careful experiments made by Dr. Oliver Lodge. The apparatus would have detected any deflection had it existed.

There is, however, a marked similarity between the Lenard and the Röntgen rays. The source of both is believed to be the cathode rays. They each produce fluorescence; each possess the power of passing through substances ordinarily opaque, the opacity increasing apparently with the density, though not in direct proportion with the density. The Röntgen rays, however, differ in the valuable property of not being so readily absorbed. The Lenard rays, though not deflected by a magnet, in free air, are deflected by a magnet when they are caused to enter a highly exhausted chamber—at least, so Lenard states. It is said that Prof. Wright, of Yale, a careful student and one whose opinion is to be regarded, does not think that the Röntgen rays differ from the cathode rays. He rather looks on the Röntgen rays as strained cathode rays.

That the Röntgen rays possess three characteristics of ordinary light ; viz., rectilinear propagation, as shown by their ability to cast shadows ; the power of producing fluorescence ; and the power of effecting chemical decomposition in a sensitive photographic plate. They differ from light, however, in nearly all other respects. If they are ether waves they may be transverse waves, which we know of ; or they may be the long-looked-for longitudinal waves. They are, however, apparently incapable of reflection, refraction or interference, all characteristic of transverse vibrations. If they are transverse vibrations they belong to some part of the spectrum that we have not hitherto studied. In the opinion of some physicists they belong to a region considerably below the red ; in the opinion of others they are exceedingly short wave lengths, possibly approaching atomic or molecular dimensions.

I have used in connection with my colleague, Dr. Kennelly, in the study of the Röntgen effect, both the character of apparatus described by Prof. Goodspeed, as well as other apparatus. Dr. Kennelly and I, charge a battery of Leyden jars with the discharge of a large Ruhmkorff coil ; we get a spark discharge and a spark gap, and then use that spark discharge, which is an oscillatory discharge, through the primary of a Tesla coil. We thus obtain in the secondary coil an exceedingly high discharge and use this to excite the Crookes tubes. The Tesla coil was immersed in rosin oil. It seems from the experiments we have made that these very rapid oscillations are not so apt to injure the tube and apparently produce better results. However, in sharp opposition to this, I hear a rumor, though it is only a rumor, that at the Johns Hopkins University they are working in the opposite direction ; viz., with very few oscillations of the primary per second. I hope Prof. Rowland, who is conducting these experiments, will soon let us know what he is doing.

Mr. Edison has been a tireless investigator in this field of physical research.

Prof. Schuster is decided in his opinion that the Röntgen rays are not the cathode rays. He agrees that the point of origin is where the stream of negatively charged molecules strikes the glass. Prof. Whiting finds gum to be the most transparent and rock salt the most opaque substance to the action of the rays. Prof. J. J. Thompson states that the cathode rays are incapable of affecting sensitive photographic plates. We all know that the ultra-violet rays, which some think are the same as the Röntgen rays, will effect the discharge of a negatively excited body. Prof. J. J. Thompson has shown that the Röntgen rays will effect the discharge of either a negatively or a positively excited body, and this whether or not the body is surrounded by the highest insulating substances known to the electrician, like vulcanite or parafine. Of course, I know that most of you will know what this means ; viz , that a leak takes place in those substances ; or, in other words, that while the Röntgen rays are passing through these substances they become conductors of electricity.

Mr. Carbutt: Do I understand you to say that no positive results have been obtained yet at the bell of the receiver of the exhaust pumps?

A. I say that I understand that no sensitive plate has yet been obtained, which, placed in the Crookes tube, will have any actinic effect produced on it by the cathode rays. When they pass outside the tube they are no longer cathode rays.

Q. But if placed on the bell of the receiver of an exhaust pump?

A. I have not tried that.

Q. Just to-day I made the experiment of exposing a pair of steel scissors; and in five minutes obtained a strong negative effect, getting my rays from the negative pole.

Q. Then they went through the glass of your receiver?

A. No, sir; they struck right on the metal scissors.

Q. Where had you your photographic plate?

A. On a bell receiver. I used no Crookes tube, nothing but just the rays as they came down from the negative pole. The plate was lying on a little table as connected with the positive pole and the rays were seen traveling down on the plate on which were laid the scissors.

A. I think you had an effect very much like the electric discharge effects shown on the screen to-night. I believe that a great many statements made concerning the ability of other sources of light to produce Röntgen rays are due either to heat effects, or to electric effects.

Dr. J. Cheston Morris asked if Edison was experimenting with celluloid plates. Prof. Houston said he did not know.

Remarks by Mr. Julius F. Sachse were as follows:

So far as the photographic properties of the new X rays of Röntgen are concerned, it is yet a question whether they will ever be of any practical value or use for photographic purposes, as the term is usually understood.

The fact that these rays can neither be refracted, condensed nor dispersed, is a fatal objection to their application to photography.

It will be noticed that all of the registered or permanent results obtained and shown here this evening are by no means photographs in the ordinary sense of the word; they are merely fixed shadows or "sciographs" obtained by the interposition of a sensitive gelatine plate.

I do not wish to be understood as depreciating this new factor in physics, nor to appear skeptical as to any practical results that may be forthcoming in the future. It is now certain that a great discovery has been made by Prof. Röntgen, notwithstanding the fact that these identical rays have been produced thousands of times, in nearly every physical laboratory in the world, and that it only needed the neighborhood of a luminous film to reveal them, and to do this was Prof. Röntgen's opportunity. The step to substitute a sensitive plate to register the shadow was a short one, and we have here to-night a practical demonstration of the results.

I now wish to call your attention to another peculiarity of the new Röntgen rays, that has just come to my notice, and had time permitted, I should have had the specimens here to illustrate my remarks.

The most exhaustive series of photographic experiments thus far made in connection with the Röntgen rays are the investigations at the Imperial experimental institution at Vienna (K. K. Lehr- und Versuchsanstalt für Photographie in Wien). Thus far no results have been obtained greater than the original skeleton hand of Prof. Röntgen. Scientifically, however, the curious fact has been learned that the actinic action of the so-called X rays is dependent to a great extent upon the medium or support that holds the haloid salts in suspension.

It appears that for some reason as yet unknown the new Röntgen rays have a peculiar affinity for a sensitive plate whose support consists of animal matter or gelatine. Now if we take a plate of equal sensitiveness, but substitute collodion for gelatine, and expose it to the action of the X rays, no effect whatever is produced. The rays seem to be absolutely inert the moment any medium is substituted for the animal support of the ordinary commercial dry-plate.

This series of experiments at Vienna consisted in testing the ordinary bromo-argentic gelatine dry plates of different degrees of sensitiveness together with argentic-iodide collodion (wet) plates—bromide collodion emulsion, and moist eosine bromo-collodion (Albert emulsion) and argentic chloro-bromide collodion plates, the latter developed with an alkaline solution.

The result of this series of experiments was that the Röntgen rays made little or no impression upon any variety of the collodion plates whether wet or dry, while upon the contrary every variety of gelatine plate, no matter whether sensitized with argentic bromide, iodide or chloride, proved a ready recorder for the Röntgen rays. The most effective plates were what are known in Germany as the "Schleusner Rapid" bromo-gelatine dry plate; they are equal in rapidity to our American plates "Sensomiter 23."

It appears from this series of experiments that the most marked difference was found in the comparison of a chloro-bromo-gelatine dry plate with a collodion wet plate, both of which were carefully tested as to their equal sensitiveness by daylight prior to being exposed to the effect of the X rays. Where the dry plate with alkaline development proved a success, the wet plate with an acid-iron development was an absolute failure.

Another peculiarity shown was that an alkaline development in every case gave better results than a neutral or acid one. Then again when a dry plate of the kind giving the best results was moistened or dampened before exposure, the sensitiveness for the X rays was greatly diminished.

Here perhaps we may find a solution to the problem why it is that none of the American results obtained by use of the X rays thus far have been equal, either in distinctness of outline or reproduction of detail, to the German sciographs. It may be to the humidity of our atmosphere, more than to the quality and character of our photographic dry plates, or the lack of skill of our experimenters, that we have to look for either cause or failure.

It will thus be seen that many new factors enter into the photographic development of the new forces. Conditions seem to arise at every turn that are entirely foreign to those encountered when we work with either solar or artificial light, and this independent from the optical features which I have mentioned.

Now the question naturally presents itself as to which kind of sensitive plate, or medium, should be used to obtain the maximum results of the actinic action of the X rays, or in other words, by what means can we obtain the best permanent Photo-Sciographs?

As to the difference between the action of the X rays upon gelatine and collodion I would venture the theory that if these results are confirmed by experiments here, that it is due to the fact that while gelatine arrests the X rays, they pass through or penetrate the collodion film. If this should prove to be the case, it would indicate the use of double-coated plates, or of a stripping film upon a support impervious to the X rays, such as a sheet of lead. By such means perhaps photographic results of still greater value might be obtained. I will here state incidentally that the Schleusner plate used in the German experiments is coated somewhat heavier than the average American plate.

I now come to another aspect of the possible development of the photographic properties of the new forces; an experiment thus far untried in connection with the Röntgen rays. For this purpose I will turn backward and take recourse to the original principles of heliography, and suggest a series of experiments wherein we substitute for the gelatine dry plate a highly polished sheet of metal, subjecting it to the action of the X rays in the usual manner, and then seeking to develop the impinged image, if there be one, with the fumes or vapor of mercury or iodine, or the two in combination, a process well known to photo experts of the old school.

Tests should also be made upon the silvered copper plate coated with the vapor of iodine and bromine and developed with the fumes of mercury (the old daguerreotype process); or upon plain sheets of polished copper, silver or tin, and developed either with vapor, or by the application of heat to the reverse side of the plate; a process known as "Hunt's Thermography."

The above experiments are well worthy of a trial in connection with the development of what may be called "photo-sciography."

In conclusion I will call your attention to a curious coincidence. It was in this room just fifty-three years ago during the centennial celebration of this Society (May 29, 1843) than an almost identical topic formed the theme for discussion, viz.: Moser's theory of "Invisible photographic rays," a theory which was then attracting great attention in scientific circles on both sides of the Atlantic. Remarks upon the subject were made by a number of members present, among whom may be named Dr. Paul Beck Goddard, Joseph Saxton, Prof. Henry and Prof. James Rodgers, all names that are still held in high esteem in the scientific world.

While upon the subject of Moser's theory, I will state that there have of late come to my notice several cases which seem to confirm his theory of latent light, or invisible photographic rays. The most marked instance was where a number of platinum prints were packed away and laid undisturbed in the dark for several months, and in several cases had reproduced themselves or formed a reverse positive picture upon the surface of the white plate paper mount which laid immediately over the print I merely mention this matter at this time so as to place it upon record, as I expect to bring it before the Society in a more formal way in the near future. As a fitting close to this paper I will quote the language of Robert Hunt, used in connection with Moser's theory and read here half a century ago, as it will apply with equal force to the theory of the unknown waves known as the X rays of Röntgen : "As a subject of pure scientific interest this discovery promises to develop some of those secret influences which operate in the mysterious arrangements of the atomic constituents of matter, to show us the road into the hidden recesses of nature's works, and enable us to pierce the mists which at present envelope some of its most striking phenomena. It has placed us at the entrance of a great river flowing into a mighty sea, which mirrors in its glowing waters some of the most brilliant stars which beam through the atmosphere of truth."

Referring to the paper read by Mr. Julius F. Sachse, Mr. Joseph Wharton asked:

Q. Will the gentleman please explain more fully what is the action of the X rays upon the more sensitive gelatine film as contrasted with their action upon the collodion ?

A. I have not had the time to verify it by experiment ; but as the case stands at present I cannot explain it except that the rays pass through the collodion film : they fail to arrest. That is the only explanation I can give at the present moment.

Q. That seems to be somewhat at variance with many of the observations that we have had set before us to-night : namely, that a number of so-called colloid bodies seem to be pervious to the ray ; while a number of the crystalloid bodies seem to be impervious. Here are pitch, gum, leather and several other bodies which are pervious to the ray (all colloids) ; while quartz, rock salt and other crystals (the speaker naming several) all appear opaque to the ray. It may be worth while to bear in mind, in future investigations, the question whether there may be a line drawn between colloids and crystalloids in transparency for the new ray, and if so to search for the reason of that distinction.

Remarks of Prof. Robb, of Trinity College, Hartford:

We are all indebted to Prof. Goodspeed for a very interesting paper and must congratulate him. There is certainly a great deal of interest in those slides. The first thing that attracted our attention in Hartford about our dry plates was the fact that on a great many of them we noticed second images which were clearly defined, but fainter than the first, having decidedly the appearance of the ordinary halo images of ordinary photography. At first glance one might think that was due to reflection. I am sure it was not due to any movement that occurred in the plate ; and I am sure it was not due to a violet region of photograph. I think exposures in bright light are a very dangerous thing. It is very possible to get shadow photographs through any of the commercial plate colors ; but in a great deal of our work where we have worked in the ordinary light we have taken the precaution of using an aluminum cover of over a thirty-second of an inch ; and we get second images to the same extent using the aluminum cover. Of course there are various explanations of it. It might be from fluorescence or other things that may suggest themselves to you.

With reference to Prof. Moser's slow plates giving better effects than rapid plates, that has not been our experience. We gave up the most rapid plate. We experimented with the most rapid plate that we could get, and we found some twenty of the plates were apparently light-struck ; and finally we settled the question they were not light-struck ; they were electric-struck by the brush discharge at the lower end of our Crookes tube.

One thing is very apparent to all of us that have been doing much work in this line—that the induction coil needs improvement. For as at present constructed they are not made to run continuously for twelve hours. They are all right to run for a few moments for showing off Crookes tubes ; but platinum terminals soon wear out or become hot ; and we have to put on new ones. In that connection I have a very good idea, due to a mechanic who does a great deal of work for me, which I will show by a sketch. The platinum point is about a quarter of an inch long ordinarily and is attached to the end of a tube having a thread on it and gradually wears away. Instead of fastening that piece of platinum directly under the tube we take a piece of platinum wire four or five inches long and place it on the end of a second metal rod which screws into the first. In that way, instead of having simply a quarter of an inch of platinum to wear off, we have some four or five inches at our disposal ; and in the next place the heat is dissipated long before it gets to the soldered joint.

I think in connection with these photographs, there are shadow photographs ; but it is remarkable what an amount of detail we can see on some of it. I have a photograph of a razor taken inside of the case which is interesting to see. When we looked at it, it was very bright in the middle of the razor—more light coming through there than at the edge.

One of my students said it must be a hollow-ground razor; and so we found it upon measurement. The photograph that we saw on the screen by Prof. Goodspeed of the aluminum plates with various holes bored in them was interesting, both as showing what can be done in the case of aluminum and what may be done in the case of other metals. From anything we know now as to the Röntgen rays, it will be impossible to tell much about armor-plating or anything of the kind; or about the molecular construction of any considerably thick pieces of the more opaque metals; but it does seem as though we can discover forms of ether vibration that will go through aluminum and go through hard rubber, and other forms that will go through pitch and things of that kind, and that certainly some day we are going to discover some form of ether vibration to which iron may be transparent. Of course we can all see what a tremendous application that would have in the mechanic arts.

We have one or two rather interesting photographs from a medical standpoint, showing its possibilities. Two or three of the students in photographing their hands discovered differences. One case of sesamoidal bone is very apparent, between the thumb and fore-finger of one of the students' hands; and then just two or three days ago we had a laboring man who was out of work from an injured hand; had been injured in a runaway accident and had gone to a local physician who has quite a reputation for doing poor work; had his hand treated; and it was never getting well; and we put it under the Crookes tube and, sure enough, there was a partial dislocation and a fracture which had never been attended to properly. Of course he was very glad to have us point out how to remedy it.

We have experimented slightly with a very interesting Crookes tube. We made a Crookes tube out of an ordinary lemonade shaker—whisky shaker—I don't know what you call it down here—with a hard rubber end in it; and the results have been very negative. We have never gotten any shadow photographs with it. We have simply taken three or four photographs with it.

Mr. John Carbutt's remarks were as follows:

My interest in the new Röntgen rays has been from the first reading of them. Being so interested in photography, when reading of the wonderful results produced by Prof. Röntgen, I naturally saw that there was going to be a much larger outlet for dry-plates. Outside of its commercial value I naturally took an interest in its scientific aspect; and the first thing that struck me was the great length of time for which the objects had to be exposed to the Röntgen rays. I therefore made it my business to investigate and to see whether or not a plate could not be produced which should be more sensitive to the Röntgen rays; and, as mentioned by Prof. Goodspeed, I experimented with the fluorescent substances, having experimented with numerous dies in the making of anthochromatic plates. I knew that several of them gave off a great deal of fluorescence. I have only produced plates printed on glass ; but I shall take up a line of experiments at once by producing some on thin celluloid ; because, for the physician and others that have cases to tend where the flat plate would be very difficult to use, the celluloid can be enclosed in an envelope —sufficiently opaque to ordinary light—and can be bound around the elbow or the shoulder or any part sufficiently round where a plate would have to lie flat ; and I think it would find in that case several uses. I have been experimenting with some professors (which matter I am not at liberty just now to mention) when I made a sciograph negative of a woman's hand in twenty minutes, plates as large as 14 x 17 being used. A film of the same size could be bound around the back, for instance ; and I think in that way that possibly the celluloid film (it is $\frac{10}{100}$-ths thick) may possibly come in use. As it has been mentioned that Mr. Edison has been using slow to quick plates, I have not as yet experimented with anything slower than a very rapid plate and am inclined to increase its sensibility ; and I think that in a measure I have succeeded, as Prof. Goodspeed has shown you. Since the sensibility of these rays is a subject that requires both study and experiment, I do not propose at the present moment to say that I fully understand all of its requirements ; and it is in its experimental stage. I shall not let the matter drop ; I find it very difficult to find any tubes that are giving the proper X rays. The one that Prof. Goodspeed is using, so far as I have seen, is the best one that I have come across. I have been using one to-day with which I gave a full half-hour's exposure and got no results. The reason was explained to me to-night in the remarks that were made that when a blue or a purple color comes from the negative or cathode end of the Crookes tube it is not efficient in giving off the X rays. There is no doubt that a great many professors who are trying these experiments and getting negative results are working with inefficient Crookes tubes.

Remarks of Dr. William Pepper were as follows :

I rise only to occupy the attention of the Society for a single moment. In pursuance of the suggestion of Dr. Minis Hays to me, we owe very much of the pleasure of this evening's discussion, he having suggested that I write to some friends in Canada ; and as a result of it, I present from Prof. Cox, of the MacDonald Physics Building at McGill University, Montreal, this brief note, accompanied by these four very excellent photographs illustrating the application of this method to surgical diagnosis.

"The MacDonald Physics Building,
"McGill University,
"Montreal, February 18, 1896.

"*Dear Sir* :—Dr. Shepherd has sent to me your letter expressing a wish to have some of our photographs for the meeting of the American Philosophical Society on the 21st.

"Our results have been in no way peculiar except that we were fortunate in making a successful application to surgery almost at the start. I have nothing to describe in the way of new methods. In fact there seems at this moment to be nothing known or tried that was not suggested in Röntgen's original paper.

"I am forwarding as likely to be of most interest a proof of the negative showing the revolver bullet between the tibia and fibula of a man's leg. This was obtained on February 7, four days after my first photograph. The print shows a copper wire fastened around the leg above as a fiducial mark ;" (here Dr. Pepper interpolated as follows to the closing of this parenthesis : "then on the Röntgen sciograph should be seen between the tibia and fibula both in the positive and negative the small darker shaded area indicating the position of the bullet") "and the flattened bullet between the bones. The latter was extracted next day ; and the patient is now nearly well enough to leave the hospital. The bullet was two inches deep in the flesh and had been flattened into a ragged-edged disc with a groove where it was lying against the bone. It had been in the leg since Christmas night. Its position was guessed at ; but the photograph converted a surmise into a certainty. On the same night, February 7, we obtained the hand of which I send a copy. It was interesting not only for its good definition (for a fourth attempt), but because it shows the rare sesamoid bones on the thumb and little finger. It belongs to a champion canoeist.

"The main ideas I have found time to try—increasing the sensitiveness of the plate by (1) placing a fluorescing screen inside the holder in contact with it : (2) soaking the plate in the fluorescing substances—I now see have been successfully carried out by Geissler, of Bonn ; so that I have nothing new to interest your Society.

"Believe me,

"Very truly yours,

"John Cox."

"The idea was to excite sympathetic fluorescence and gain intensity by resonance."

Dr. Pepper, continuing with original remarks :—As to Mr. Carbutt's remark as to obtaining flexible discs for curved surfaces and this (from Prof. Cox) interesting contribution as regards the diagnosing of internal conditions, I would say the excitement has spread the world over : every day I am receiving numerous letters, telegrams, visits from people at a distance, coming to ask whether it has yet reached a point to become an aid to internal diagnosis. I will not at this late hour occupy the attention of the Society by calling their thoughts to the obvious, the very great difficulties of this method. The tissues which are inaccessible to the hand in palpation are guarded so often by bony surfaces that the danger of shadows existing—which will be almost more confusing than the difficulties which surround our present means of diagnosis

—is very obvious. The field of investigation is of enormous proportions. The assistance of Prof. Houston and his associate, Dr. Kennelly, is promised in entering on an elaborate series of investigations in this direction. Whatever may be the result, we promise ourselves the pleasure of submitting them at a later period to the attention of the Society.

I have also here a few photographs of Dr. Henry Cattell; but as most of them have been published before I do not know whether he would care to show them at present.

Mr. Wharton exhibited a tube containing argon produced by Lord Rayleigh, which was presented by him to Dr. Theodore Wm. Richards, of Harvard University. This tube being arranged for sparking was introduced into the current of a Ruhmkorff coil, where it made a fine display of color.

A number of the members examined this with a spectroscope provided by Dr. Goodspeed, and thus observed very clearly the characteristic lines of argon.

Stated Meeting, March 6, 1896.

President, Mr. Fraley, in the Chair.

Present, 24 members.

Mr. Henry Pettit, a newly elected member, was presented and took his seat.

Correspondence was submitted as follows:

Letters accepting membership from Dr. A. E. Kennelly, Philadelphia; Prof. William Pitts Mason, Troy, N. Y.; Dr. Henry C. McCook, Philadelphia; Mr. Henry Pettit, Overbrook, Philadelphia.

Letters of acknowledgment from Prof. A. E. Nordenskiold, Ph.D., Stockholm, Sweden (143, 146); R. Accademia di Scienze, etc., Modena, Italy (143, 144, 145, 146); Buffalo Library, Buffalo, N. Y. (148); Dr. Albert P. Brubaker, Philadelphia (147, 148); Hon. J. D. Cox, Cincinnati, O. (148); Colorado Scientific Society, Denver (148); Bishop Crescencio Carrillo, Merida, Yucatan (148).

Accessions to the Library were reported from the Linnean Society of N. S. Wales, Sydney; Société Hollandaise des Sci-